FROGS AND PADDY: PROBLEMS OF MANAGEMENT [1]

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Frogs are claimed to enhance agricultural productivity. However, this statement, while likely true, deserves test. The difficulty is that there are multiple species and growth stages of frogs involved, and observations indicate that these species differ among regions and, more important, seem to differ with the cycle of paddy production. The stages of cultivation are briefly summarised, and the ways this seems to affect the populations of frogs are noted. Frogs appear to use paddy zones both for feeding and breeding. However, the stages of paddy production likely affect the effectiveness of predators. This paper attempts to ask some questions about possible effects and make some suggestions regarding possible studies. These may lead to maintenance of biodiversity and simultaneously establish practices that might have a desirable effect on agricultural productivity.

INTRODUCTION

Recently, there have been several conferences decrying the drastic reduction of frog populations, indeed of number of frog species (Anonymous 1990, Blaustein and Wake 1990; also see Froglog Publications of the Declining Amphibian Populations Task Force. IUCN/SSC, Corvilia, OR. U.S.A.). India was mentioned prominently in a number of associated news releases, perhaps because the Government had some time earlier made the export of frog legs illegal. The cost, in terms of lost revenue, had been justified on the grounds that the animals were useful in pest control and that their harvest involved much cruelty. However, in global terms each national ban has seen increased trade elsewhere to meet market demands.

There is little question that harvesting of wild animals for skins, food and sport often involves some cruelty; yet this may be resolvable by the development of humane methods of killing. However, the claim that frogs facilitate pest control is less clear cut, involving evaluation of the problems of overexploitation by developing sustainable management.

Discussion with the few specialists on Indian amphibians and a review of the literature reveals remarkably little solid evidence regarding the species of frogs involved and their effects on agricultural production. This raises questions whether the present action is indeed useful, and perhaps as important, whether it is sufficient for protecting the frogs and aiding the farmers. This issue may well require further study and experimentation.

It is here proposed to ignore for the moment the frogs of the Indian mountains, bogs and rainforests, as these represent small often endemic groupings that need protection, but likely could only be saved by protecting their environment. In contrast, most of the country is used for agriculture and most of the temporary wetlands are in paddy, devoted to the production of rice and similar cereals. Their frogs are here used as an example, commenting on some

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issues observed during survey collecting in India and Sri Lanka. The frogs associated with other kinds of agriculture, those of coconut palms, of tea, coffee and cardamom plantations, pose different questions and potentially involve different protective schemes.

Which frog is it?

It seems of considerable interest to consider the way that cultivation impacts on the biology of the frogs that now occupy paddy regions. However, before the life history of these animals can be discussed, it is necessary to know the species involved, where these occur and how widely they range. This is particularly important for a region such as India which seems to have far ranging lowlands, utilized for agriculture involving various kinds of intermittent flooding.

Past reports have referred to species, such as *Rana cyanophlictis*, *R. hexadactyla*, and *R. tigerina*, as ranging from the extreme south of the Peninsula to the foothills of the Himalayas. However, such statements have rarely been confirmed by a single researcher who examined samples from all parts of the range by modern techniques or better yet, travelled from one region to another in each comparing the "common" forms. Instead, local investigators have examined local frogs, and compared them to reference accounts in the inadequate faunistic handbooks; however, these allow discrimination only of the obviously different. Modern analyses of the frog faunas of Europe and North America have shown that the widespread "common" species often involve replacement by very similar, but discrete species. It is likely that the same situation will apply to India as well.

For instance, the American spotted grass frog used to be referred to as *Rana pipiens* and assumed to represent a single species ranging from Canada to Mexico. Unfortunately, recent examination has shown that the population includes more than four distinct species differing in mating call, morphology, and color and, of course, in several biochemical characteristics. The effect of these frogs on the local insects clearly differs. The situation in Europe is even more complex, the common frogs involving hybrid swarms. Consequently, it is necessary to apply call and biochemical, as well as morphometric techniques for an assay of the distribution of the seemingly wide-ranging Indian species.

The study of frogs normally proceeds by two major techniques. The first is to catch a series of each kind of frogs observed and to preserving it for later careful study in a museum setting. One may then establish differences in color, shape, size, and see how these differ among geographical regions. During the process of collecting one must also search for juveniles and females (which often differ in color and proportions). As these do not advertise their presence, they tend to be more difficult to take; obviously, they are as important to an understanding to the fauna. Collection should proceed nocturnally as the frogs are then most active. The collecting effort should be amplified by a diurnal search, concentrating on tadpoles in the water, and looking for adults in hiding places that they occupy during the day between calling intervals. Many frogs hide underground during the dry season and become active during the monsoons; this has to be taken into account in establishing an adequate faunal sample.

A better approach to sampling utilizes the mating patterns of frogs. Commonly, their males travel to various bodies of water and call from these. Other males move toward sites from which calls originate and join the chorus which may ultimately reflect the size of the body of water. Females are attracted by the calls and at some moment approach the males; mating occurs thereafter. Some males start to call away from the water and only reach ponds or streams very briefly at the peak of arousal, with the females there meeting them.

The call of each species of frog in a given area will be unique; this allows the females to approach the conspecific males. This also lets the collector assay quickly which species are "available" at a given site. It is relatively easy to determine the number of calls and then to enter the area and locate and identify unequivocally the specimen generating each sound. A small tape recorder permits one to obtain a record of local calls; the records may later be compared electronically to establish their characteristics and possible local variation. As frogs will also differ in the site from which they call, one mainly needs a good ear to make the assay.

These techniques allow an initial survey which naturally provides mainly a preliminary overview. This needs to be followed by two steps. The first should establish the range of widely distributed species by checking whether their morphology (color patterns, morphometrics, gland patterns, etc.) is constant or shows discontinuities. Tape records of frog calls can be compared similarly to search for discontinuities. Immunological and molecular studies should then sample any populations that differ from adjacent ones, but should also determine whether widely-ranging are homogeneous by these criteria as well. The second step consists of what might be called local studies, that deal with the details of the natural history of each species.

Paddy production

The way rice or paddy is produced likely has major implications for the biology of the frogs. The process of growing rice requires that the fields will be flooded regularly. The image of women, wading in water while they plant the rice, is a common sight. However, rice fields are hardly a constant wetland; for much of the time, they are dry. Consequently, we know that frogs enter the paddies and that they call and presumably breed there, but we know little of what happens next.

Paddy production starts with the monsoon, although irrigation could generate equivalent effects. The fields are subdivided by narrow dams, rising some 30 cm above them (on flat areas, in hilly zones the downhill dams may be much higher). After the harvest an interim grassy vegetation forms. This is often grazed. The process starts with a flooding of the fields, either due to the retention of the rain waters, or by channelling in irrigation water. During this initial flooding stage of production the vegetation becomes soaked, but the amount of irrigation water tends not to cover the tops of the vegetation.

The second, first-plowing stage is that of breaking the soil, often by buffalo-pulled plough. The mat of grasses and herbs is lifted up and divided by the plough. Sinking down, the divots rest on one another and the intermittent zones become flooded channels. Often the footprints of the buffalo provide a series of intermediate holes that fill with water.

The third stage is sometimes referred to as mudding. Buffaloes are caused to walk back and forth, dragging various implements that break up the root mass and turn the substrate into a muddy soup. Mudding proceeds initially for a small portion of the acreage and here a dense bed of seedlings is grown from seed. As the emerging leaves reach a height of perhaps 20 cm, the rice plants and their roots are pulled out and bundled.

The fourth stage is planting. The small bunches of seedlings are now replanted in a more open spacing (perhaps 5 to 10 cm apart) in which they can continue to grow. During the planting – growing phase, the surface continues to be flooded.

After some time, the plants mature. The water supply then is diverted from the fields, which are allowed to dry. The rice is cut and threshed, often on the same fields on which it was grown. Sometimes, the husk is burned here, although the straw commonly serves other purposes.

The land then is permitted to remain fallow for some time, allowing grasses and annuals to grow until the following season. Obviously, there are local variants in the production pattern, depending on the region, the amount of fertilizer applied, the use of the intercrop vegetation as part of the nitrogen enrichment scheme and similar factors. Also these are parallel differences in the nature of the ditches that provide water during the start of the growing season, the distance over which the water is diverted and the proximity to permanent bodies of water.

Primary observations

Observation of the kinds of frogs observed in association with paddies indicate that the frogs seem to have local options, but also that they exhibit certain general trends. Patchiness seems to be the key to understanding the kinds of frogs found, and this reflects the nature of the areas adjacent to the particular field. Its distance from the edge of the overall region planted in rice affects the species composition. This is also affected by the kinds of vegetation occurring adjacent to the planted region; forest, tree garden, coconut palm, plantain, tea or human housing each have effects on the composition. The composition is also affected by other microecological factors, such as the recent history of the agricultural work, activity in adjacent patches and the state of the weather. However, the initial observations need to be tested and evaluated statistically.

The most important result of the initial observations has been the observation that the community of frogs observed in a paddy area commonly involves from six to a dozen species, with only one to three of these actually being "large" frogs. However, prereproductive juveniles of the very large (<100 mm snout-vent length) species (*Rana hexadactyla* and *R. tigerina*) also contribute to the population in each paddy. Rarely does one observe (collect) as many females as males; this does not appear to reflect only the silence of the latter, but suggests that the females often enter the flooded paddy later. There is a strong "edge effect" with distinct populations occurring adjacent to other paddy fields than adjacent to zones with other agriculture or fallow zones. Commonly, one finds that calling males of particular species clump within particular paddies; thus, one wades through subzones in which one or another call pattern predominates.

The number and kinds of frogs observed change drastically with agricultural phase. This is very clear in areas in which the individual paddies are at a different stage of cultivation. Each frog species found in a particular patch then reflects local circumstances much more than those of the overall region. The amount of vegetation, particularly of that rising above the surface and the size and permanence of mud islands and of intermediate flooded regions appear most significant.

Large frogs were generally observed in the paddy only during the first cultivation stage. Their adults sit and call close to the edges of the unplowed fields with more specimens seen where the fields are adjacent to stone walls and tree covered edges. Juveniles of these species seem to range further into the open fields. Only some of the smaller species cooccur with these forms. Only after the first plowing do the diversity of calls reach a maximum, by this time the water surface tends to be subdivided and the paddy represents a series of independent pools and channels separated by strips of soil and vegetation.

With the exception of one or two species of ranids, including the skittering frogs, most species of smaller frogs inhabit and call adjacent to patches of vegetation and soil. Their calling sites are microecologically distinct. Common specific calling sites are small patches of open soil, open water, bits of grass, paddy bunds (from which some forms call projecting out over the water, whereas others find, or build, cavities *into* which to call), and small (diameter <10 cm) pools with the animal floating in the center or standing along the edge (calling upward). Many species seem to produce ventrilocal effects, as if the call is reflected or misdirected.

As the phases of cultivation change the microecology of the paddy surface, one can see a basis for the shift in frog usage pattern. However, more is involved than simple replacement, as the apparent density of particular species seemingly rises and falls. Many individuals of the species that characterize the later stages are either absent or silent during the earlier ones.

Where do all the frogs go?

It is likely that much of the observed pattern reflects predation. The described patterns of agricultural practice expose more and more individuals to observation and attack. The sheltering vegetation becomes reduced and may disappear during mudding. Separate predation patterns occur during the day and night.

During the day, one observes many species of wading birds, including herons and egrets, some of which will follow the plow, as they travel on or walk with buffalo traversing marshy areas. As frogs jump from the feet or the plow, they are detected and caught. At night, there may well be a pattern of bat predation, as some of these detect moving frogs. This again suggests the importance of the cultivation stage to frogs survival; it would be much easier for a bat to detect a frog in an open area than amid partly flooded vegetation. I am informed that there are no sound-hunting bats in southern India (Neuweiler 1990). This leaves open the reason for the ventriloquists; what other predator may be listening to these frogs?

The probability that bats are significant nocturnal predators of frogs is supported by two incidental observations. First, during nocturnal travel by car, one commonly sees bats cruising very low, within 30 cm of the road surface. This seems unusually low for catching flying insects. Also, most of the frogs seen crossing the roads, appear to traverse open areas with a series of jumps and then crouch down resting close to the vegetated berm, rather than moving one jump at a time and sitting up in the middle of the road.

Missing information?

The preliminary observations indicate

that the paddy populations are comprised of multiple species of frogs and that the species composition changes with the pattern of cultivation. However, these observations leave open many questions, some of which require further observation and other experiments. The two key questions that need resolution are: How important are the individual frogs we see to the survival of their species? and how important are these frogs to the ecological balance of the field and to pest control? We really have only minimal data on the first and no data on the second set of questions.

To answer the first question, we need information on when the females reach the males and where and when the eggs are deposited. Next we need to know what happens to the tadpoles during the phases of paddy production; are these species maintained by the reproduction we see in the paddies or is most of the next generation produced in adjacent areas. When do the young metamorphose, does this happen in the flooded paddy area or in adjacent zones and where do the small frogs go thereafter? How long do the metamorphosed frogs stay near the paddies, and where do they pass the dry season? What is the survivorship of each of these frog species, i.e. how many eggs are laid (per clutch, per season), how many tadpoles metamorphose into frogs, and how many frogs. Do aspects of the cultivation practice, for instance, the gradual desiccation of the paddy affect the time of metamorphosis, as it does in some American frogs? These questions require detailed observation of the animals and of their offspring throughout the year. Also, it may be necessary to keep some areas enclosed or fenced in order to study the effect of predation. Various simple experiments should begin allow one to provide and test answers to such questions about the natural history of the species.

To answer the second set of questions, we need information on how many frogs there are for each species and what might be their mass per hectare. Next one needs to know who eats what, when and where. Which of the frogs indeed feed in the paddy areas, at what age and size stage, what are their prey items and what is the mass of prey consumed? Do any of the large frogs eat small frogs? Do they deter predators on the smaller species? Some answers may be obtained by examining the stomach contents of captured frogs. Obviously such examination must occur very quickly after capture. For small frogs, the animals must be preserved immediately (so that digestion is then arrested); for larger frogs one should be able to experiment with stomach flushes, some tests being necessary to assure that no prey will be retained in the stomach.

Once the prey has been identified one needs to determine whether the species of molluscs, annelids and arthropods involved have any direct or indirect bearing on crop productivity. For that matter one may also ask whether they represent vectors for diseases of man or domestic animals. On the other hand it becomes necessary to consider the effect of the chemicals often applied, those used as fertilizers, insecticides, vermicides and fungicides. What is their influence on insect populations and, important in the present context, on the eggs, larvae and adults of the frogs. Do the populations of frogs show any developmental abnormalities (teratologies), the frequency of such deformations, whether affecting limb arrangement or color pattern, often indicates the level of toxic materials in the environment.

A General Overview

The main difficulty with the general approach to the protection of Indian frogs (and for probably other species as well) is that we assume, but we do not know. The prohibition of the export of frog legs resulted in some loss of foreign exchange; however, the documented benefits derive mainly from humanistic considerations. The issue of "pest control" deserves much further study. For very few areas have there been longitudinal (long-term) baseline studies, giving documented quantitative observations, repeated year after year. It "seems" that there are "lots" of frogs and that these may have an effect on paddy production, but is this true? How many frogs and of which species were there a decade ago, five years ago, at the time the export ban was imposed, or now? Which species are most useful and are these the ones that are being protected? What additional resources should be invested, perhaps in maintaining permanent water zones, near paddy fields. Surveys should be carried out using standardized methods (Heyer *et al.* 1993).

We need observations to answer such questions, but we also need ecological experiments. What is the effect of frog removal on conspecifics or other species? What would be the effect of predator exclusion (assuming that we are correct about which predators are significant? How important are undisturbed waters near paddy areas, whether as ponds or as canals? Are terrestrial shelter zones important and if so are holes and tunnels significant? Folklore suggests that the tunnels of the dams dug by rats and crabs are entirely deleterious; might they have a different kind of merit, perhaps in providing shelter for the larger species of frogs?

The several kinds of rice represent a key component of human diet. Their cultivation involves a relatively enormous area. Frogs are certainly an obvious and substantial aspect of the rice field flooding and planting cycle and estimates suggest that their biomass is a substantial portion of the overall amount. Theoretically they should affect the yield in several ways. Yet we do not yet know how many species of frogs there are in different regions and even less how they survive and what effect they have on our well being.

The need to know more about this potentially critical system demands that more teachers and scientists actually proceed to join the villagers in the paddy fields. It also requires that artificial barriers to carrying out such studies be removed, indeed that the agencies charged with protecting Indian wildlife actively foster both local and central studies in many regions.

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References

Anonymous (1990): Declining amphibian populations —A global phenomenon? Workshop of Board of Biology, National Research Council. Finding and Recommendations, 9 pp.

Blaustein, A.R. & David B. Wake (1990): Declining amphibian populations — A global phenomenon? *Bull. Ecol. Soc. Amer., 71(2): 127-128.*

Heyer, W.R., M.A. Donnelly, R.W. McDiarmid, L.C. Hayek & M.S. Foster, (1993): Measuring and monitoring biological diversity: Standard Methods for Amphibians. Smithsonian Institution, Washington, D.C.

Neuweiler, G. (1990): Auditory Adaptations for prey capture in echolocating bats. *Physiol. Revs., 70(3):* 615-641.